

Amendments to the Specification

Please replace paragraph [0028] with the following amended paragraph:

[0028] In this LEFET structure, the only electrode interfering with the guided wave is the gate electrode. A recent study [M. Pauchard, J. Swensen, D. Moses, A. J. Heeger, E. Perzon, M. R. Andersson, *J. Appl. Phys.* **In Press**, 94(5), 2003, 3543] has demonstrated that indium-tin-oxide (ITO) is a promising gate electrode material because it introduces only small losses compared to other materials, e.g. Au or n-Si. Figure 1 (b) shows a schematic picture of the waveguide structure in the channel of such an FET. The structure forms an asymmetric double waveguide because the refractive indices of the ITO (index n_4) and the light emitting polymer poly(2-(2',5'-bis(octyloxy)benzene)-1,4-phenylenevinylene (BOP-PPV) [D. M. Johansson, X. Wang, T. Johansson, O. Inganäs, G. Yu, G. Srdanov, M. R. Andersson, *Macromolecules* **2002**, 35, 4997} (index n_2) are higher than that of air (index n_1), the gate insulator SiO_2 (index n_3) and the glass substrate (n_5), respectively. The index profile of the waveguide and the mode intensities of the two guided TE modes are shown on the right hand side of Figure 1 (b). The letter "d" refers to the thickness of the gate oxide SiO_2 and L is the length of the pump stripe used in the optical experiments described in the text. The refractive index profile and mode intensities of the two supported TE modes of the waveguide are shown on the right side of Figure 1(b). The optical modes propagate along the z direction, and the light leaves the structure at the edge of the device.

[0034] Alternatively, the source and drain can be implemented using the structure shown in Figure 2, in which the semiconducting polymer is a bilayer comprising a luminescent polymer layer next to the gate dielectric (SiO_2) in the figure and a second layer comprising a material useful for making a light emitting electrochemical cell (LEC). After making the p-i-n junction of the LEC by applying a source-drain voltage, the resulting n-type and p-type doped regions provide the contact through which electrons and holes are injected. In the structure of Figure 2, the light emitting electrochemical cell (LEC) [Q. Pei, G. Yu, C. Zhang, Y. Yang, and A. J. Heeger, *Science* **269**, 1086 (1995); Q. Pei, Y. Yang, G. Yu, C. Zhang, and A. J. Heeger, *J. Am. Chem. Soc.* **118**, 3922 (1996)] enables the injection of electrons and holes from the source and drain. In Figure 2, the LEC layer can be a conjugated polymer mixed with an ionic transport medium such as disclosed by Pei et al. [Q. Pei, G. Yu, C. Zhang, Y. Yang, and A. J. Heeger, *Science* **269**, 1086 (1995); Q. Pei, Y. Yang, G. Yu, C. Zhang, and A. J. Heeger, *J. Am. Chem. Soc.* **118**, 3922 (1996)]. Alternatively, the LEC layer can utilize a single-component polymer such as, for example, poly[9,9'-bis(6''-(*N,N,N*-trimethylammonium)hexyl) fluorene-*alt-co*-phenylene]bromide (PFN^+Br^-) as the active material. PFN^+Br^- is a member of a class of semiconducting polymers that is water soluble. In the solid state, PFN^+Br^- is a salt comprising the PFN^+ polycation with Br^- as the counteranion. Since the Br^- is mobile at elevated temperatures, the layer in Figure 2 which is designated as "polymer LEC" can be made into a p-i-n junction in-situ by applying a voltage while the structure is held at a sufficiently high temperature. After, creating the p-i-n junction, the structure is cooled to room temperature, thereby freezing in the p-i-n junction [J. Gao, G. Yu, and A. J. Heeger, *Appl. Phys. Lett.* **71**, 1293 (1997); G. Yu, Y. Cao, M. R.

Andersson, J. Gao , and A. J. Heeger, *Adv. Mat.* **10**, 385 (1998)]. LECs have been successfully fabricated from single component systems such as PFN^+Br^- [L. Edman, M. Pauchard, B. Liu, G. Bazan, D. Moses and A. J. Heeger, *Appl. Phys. Lett.*, *in press*) **83**(22), 2003, 4488].

[0039] When the Bragg reflector is constructed to reflect at ~~the ASE~~ the ASE wavelength, the modified LEFET will emit coherent laser radiation above threshold. Other methods of achieving the necessary resonant structure with feed-back are well known in the art. For example, simple reflection from the edge of the polymer layer can be used (see Figure 1(a)).

[0041] Preferred embodiments for Layer 1 include the class of luminescent polymers well known in the art. Examples include soluble derivatives of poly(phenylene vinylene), soluble derivatives of polyfluorene, copolymers containing phenylene vinylene monomers, fluorine monomers, phenyl rings and the like. This class of luminescent semiconducting materials has been widely disclosed in the literature describing the science and technology of polymer light emitting diodes. Specific examples are given in the following: [U.S. Pat No. 5,881,083 and references therein; M. D. McGehee and A. J. Heeger, *Adv. Mat.* **2000**, 12, 1 and references therein]. More generally, thin amorphous films comprising small molecules (rather than polymers) can be used ~~in~~ in the semiconducting luminescent layer. Such small molecule systems are well-known in the technology of organic light emitting diodes (OLEDS); there are many potentially useful structures documented in the OLED scientific literature and the OLED patent literature

[0045] Preferred embodiments for the substrate include transparent materials, for example glass ~~or~~ or plastic. Plastic substrates offer the special advantage of flexibility. The use of silicon as the substrate (with a thin layer of doped Si as the gate) is appealing in order to integrate the polymer LEFET lasers as components on silicon chips. Although absorption losses in the silicon must be avoided, the amplification of the cut-off mode which propagates at the polymer/insulator interface minimizes such losses.

[0054] As shown in Figure 5, the ASE threshold (optically pumped) is a sensitive function of the thickness of the gate insulator. With a 200 nm SiO_2 gate insulator, the ASE threshold is 300 kW/cm^2 ~~is if~~ an n-Si gate electrode is used and 200 kW/cm^2 if Au is used. This increase of the threshold by a factor of 80 – 120, compared to a BOP-PPV film on pure SiO_2 results from losses introduced by the nearby electrode. The use of a 130 nm thick ITO gate electrode leads to a much lower ASE threshold, $I_t = 30 \text{ kW/cm}^2$. The influence of the ITO on the threshold is not explained by a reduction of the PL efficiency, as in the case of the other electrode materials, but rather by the formation of an asymmetric double waveguide structure. The cut-off condition for the amplified mode varies with the SiO_2 thickness and influences the ASE threshold and the ASE wavelength. The mode structures and the ASE are sensitive to the ITO thickness. At an ITO thickness of 60 nm, the mode structure changes from a double to a single waveguide. This transition is followed by a reduction of the ASE threshold. For an ITO thickness of 12 nm an ASE threshold of 4 kW/cm^2 was measured. Thin ITO films are an excellent choice for the gate electrode for LEFETs.

[0060] Figure 7 (a) presents typical spectra, $I(\lambda)$, obtained from a BOP-PPV film in the configuration sketched in Figure 1b, with 251 nm SiO₂ and 140 nm ITO on glass, at different pump powers with a pump stripe length of L=2 mm. The spectra are dominated by an emission band centred at 545 nm with a full width at half maximum (FWHM) of 4 nm. The inset shows the output intensity at this wavelength as a function of the pump power. The dashed line indicates the optical gain threshold, I_t , for the guided mode. Figure 2_7 (b) represents the measured optical gain threshold (squares) and ASE wavelength (open circles) for similar samples with different oxide thicknesses. The ASE threshold increases exponentially with decreasing thickness of the SiO₂ (d), as a result of the losses introduced by the nearby ITO gate electrode.^[19] The wavelength of the maximum ASE intensity (open circles) is around 545 nm for thick oxide layers and shifts towards smaller wavelengths for d < 200 nm.

[0061] As demonstrated in Figure 2_7 (a), there is a second emission band with wavelength longer than that of the amplified guided mode; i.e. from the cut-off mode. At pump powers below the threshold of the guided mode, the edge emission is dominated by the longer wavelength emission peak with FWHM of 6 nm.

[0064] For SiO₂ thicknesses d > 200 nm, $\lambda_{\text{cut-off}} > 545$ nm, and the wavelength of the amplified guided mode (circles) is pinned at the wavelength with highest DOS(λ); i.e. equal to the luminescence maximum of BOP-PPV. For d < 200 nm the cut-off condition shifts below 545 nm. Since wavelengths longer than $\lambda_{\text{cut-off}}$ cannot be guided in these structures, a blue-shift of the wavelength of the amplified guided mode is observed in structures with d < 200 nm. This wavelength (545 nm) corresponds exactly to the wavelength of the guided modes with the highest net gain, as seen in the contour plot. The wavelength of the amplified guided mode corresponds to the wavelength of the maximum value of $\Gamma(\lambda) \times \text{DOS}(\lambda)$ that is available in the guided region for a given d (see Figure 3_8(b)). Therefore, the influence of the polymer/electrode separation on the wavelength and threshold of the guided mode can be explained by the effect of the cut-off.

[0068] Figure 9 shows the gain spectra obtained by this method for sample I at three different pump powers: 12 kW/cm² (dashed), 30 kW/cm² (dash-dotted) and 41 kW/cm² (solid). There are three important observations: First, the gain spectra exhibit a clear spectral separation between the amplification of the cut-off mode and the guided mode. That separation demonstrates nicely that the amplification takes place at two well-defined and separate wavelengths, corresponding to the cut-off mode and the guided mode. Second, the gain peak at higher wavelengths does not match any vibronic sideband of the BOP-PPV emission. Third, high positive net gain, $g(\lambda_{\text{cut-off}}) \approx 30$, is observed for the cut-off mode at pump powers where $g(\lambda_{\text{guided mode}}) < 0$. The data clearly demonstrate relatively low threshold optical amplification of the cut-off mode.